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(71) Applicant(s)
Nordson Corporation
(Incorporated in USA - Ohio)
28601 Clemens Road, Westlake, Ohio 44154 - 1119, United States of America

(72) Inventor(s)
Matthew Littlefair

(74) Agent and/or Address for Service
Lloyd Wise, Tregear & Co
Commonwealth House, 1-19 New Oxford Street, LONDON, WC1A 1LW, United Kingdom

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(56) Documents Cited
GB 1112255 A GB 0774477 A EP 0647086 A1
EP 0178852 A1 WO 97/33456 A1 WO 97/16054 A1
WO 91/02443 A1 CA 002224300 A1

(58) Field of Search
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INT CL[6] H05B 41/14 41/16 41/20 41/23 41/231 41/232 41/233 41/24 41/26 41/28 41/29
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(54) Abstract Title
Discharge lamp ignitor circuit

(57) An ignitor circuit for a gas discharge lamp 8 has an inductor 34 connected in parallel with a capacitive means 28, 30 which includes the lamp connecting lead capacitance 30, the inductor 34 and capacitive means 28, 30 forming a resonant circuit which generates a striking voltage across the lamp leads when driven at its resonant frequency. The capacitive means may include a variable capacitor so that the resonant frequency can be set at a desired value for various lengths of lamp lead. The ignitor circuit may be driven by a resonant inverter 2 having a resonant circuit formed by a capacitor 20 and an inductor 18 in series with an inductor 32 forming a primary winding on a transformer 26 having the inductor 34 as a secondary winding. The voltage developed across capacitor 20 is connected to a rectifier and DC link circuit 4 providing a DC supply voltage which is applied to a DC lamp (38, Fig.2) or to an AC lamp 8 via a low frequency inverter 6. The resonant frequency of the ignitor circuit 28, 30, 34 may be slightly higher than that of the resonant inverter 2. Inverter 2 is started at a frequency well above resonance, the frequency then being reduced towards resonance, so that the maximum ignitor voltage is generated simultaneously with maximum lamp voltage obtained from the inverter 2 via link 4 and inverter 6. Once the lamp strikes, lamp current flow through winding 34 saturates transformer 26 thus disabling the ignitor. To ensure that the transformer 26 is continuously saturated, after lamp starting, even when the square waveform lamp current passes through zero, the transformer may have an additional winding formed by two coils (56, 58, Fig. 3) connected to the DC link 4 to pass a saturating current but wound so that the voltages induced in coils (56) and (58) during ignition cancel one another.

The lamp may be used for UV curing of material on a moving substrate in printing or coating apparatus, de-ionised water being passed through a quartz tube (74, Fig.5) to filter infra-red radiation.

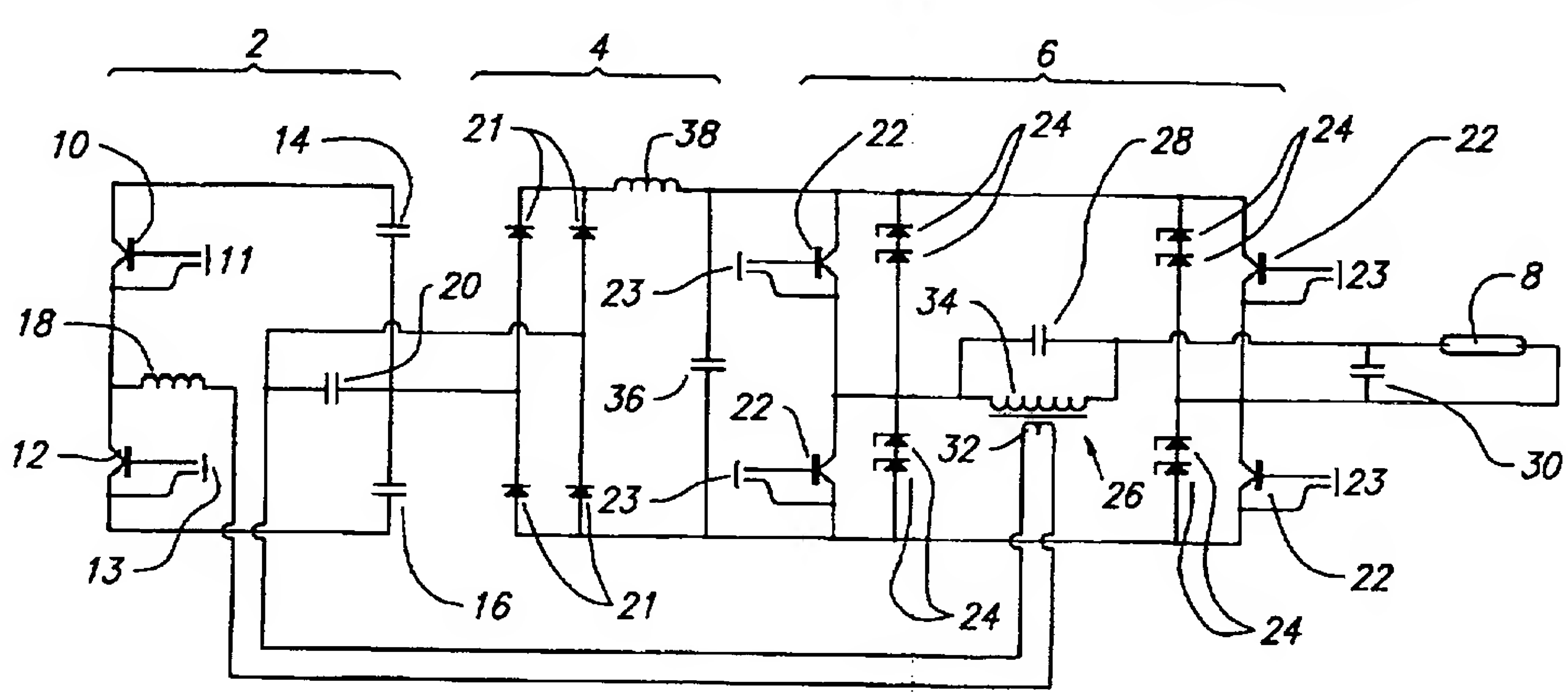

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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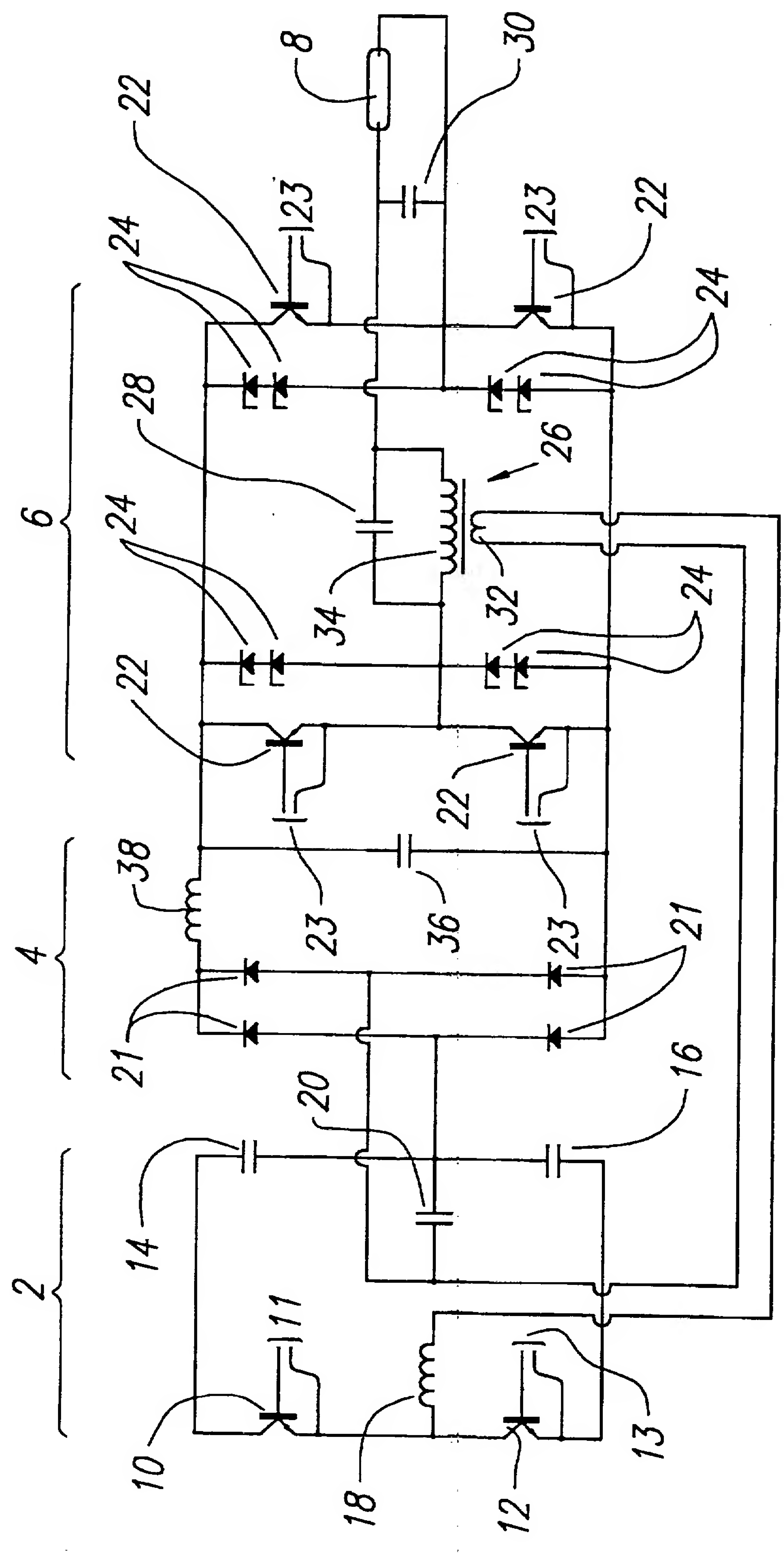

FIG. 1

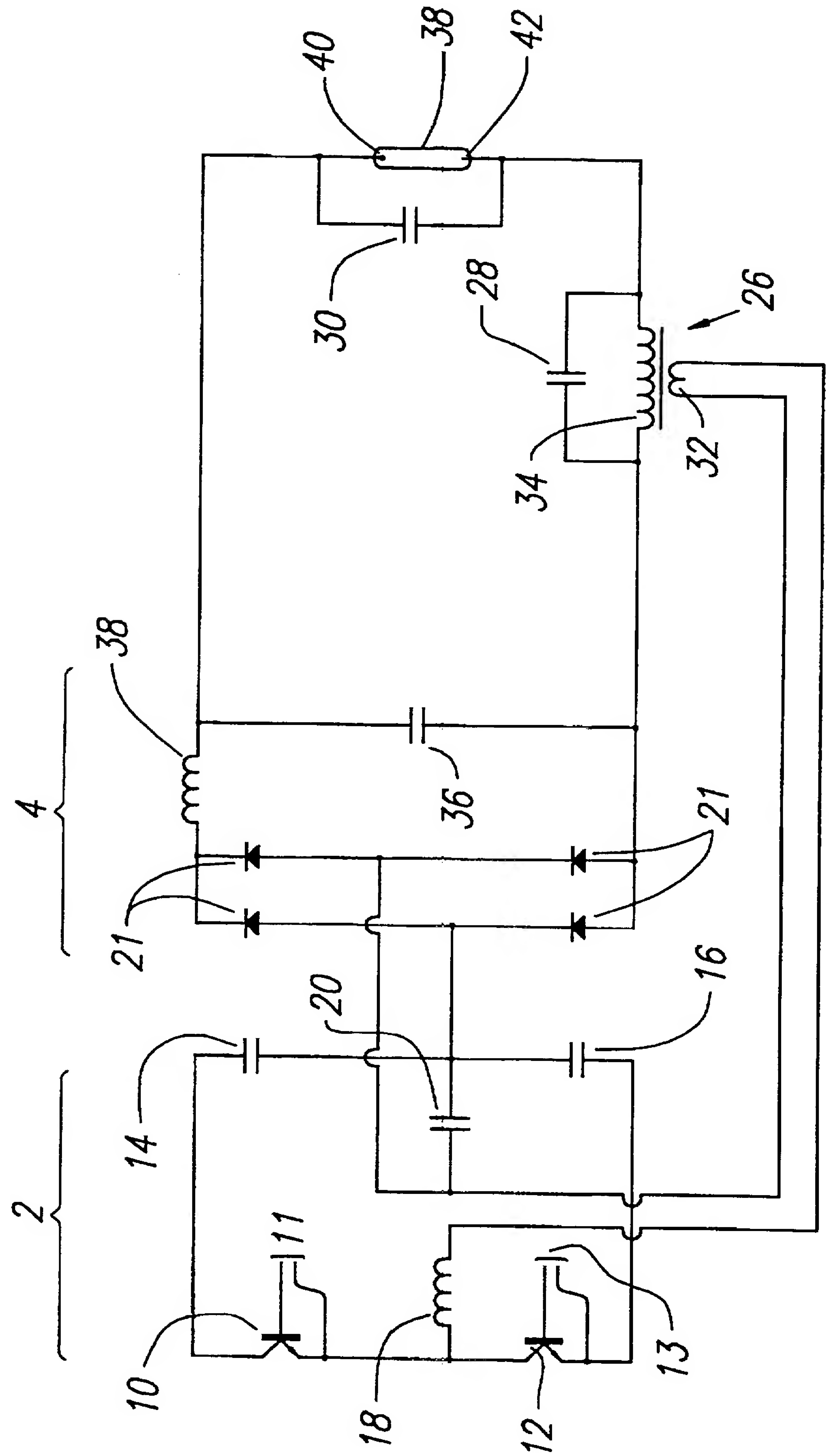

FIG. 2

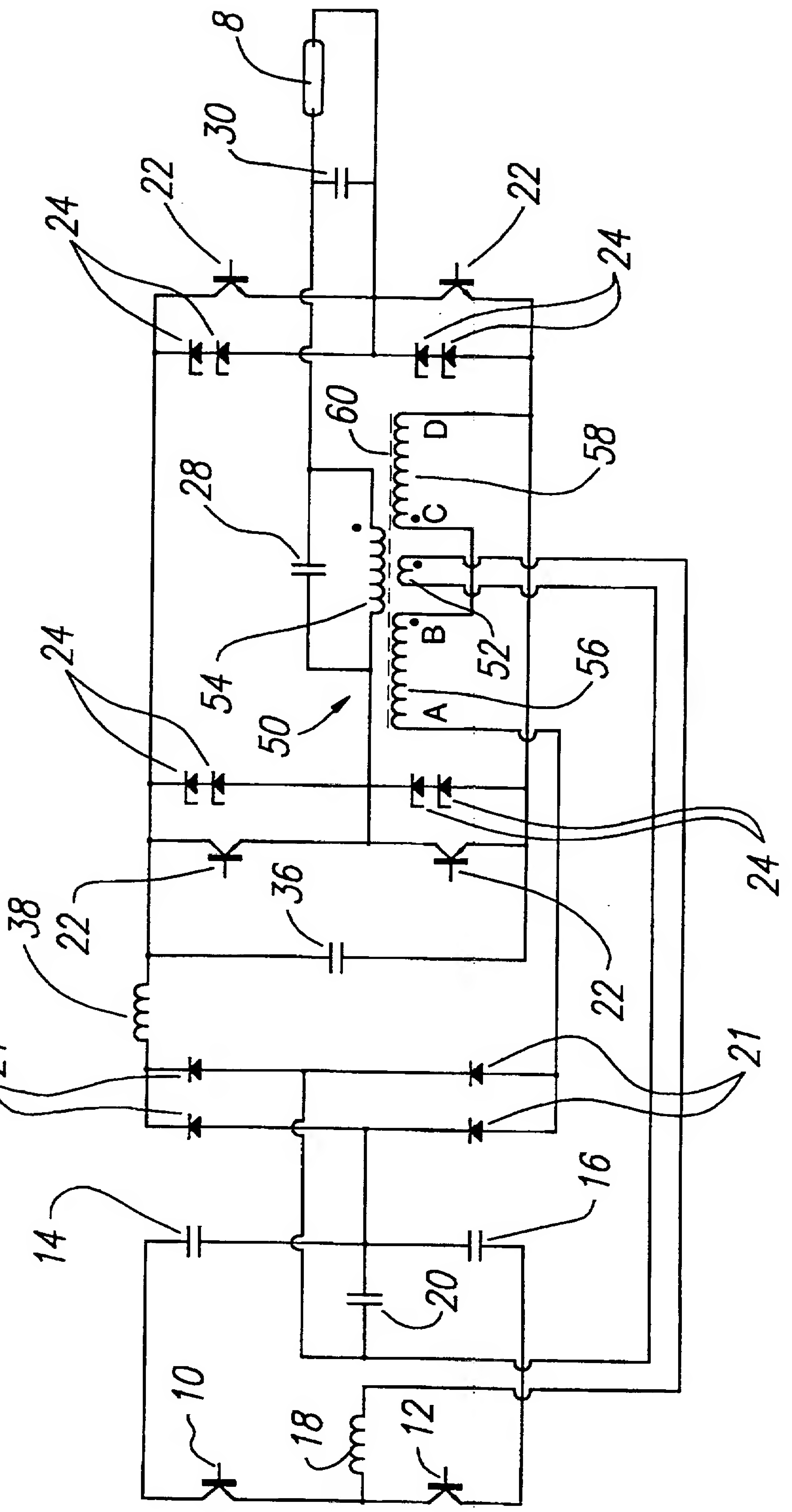
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FIG. 3

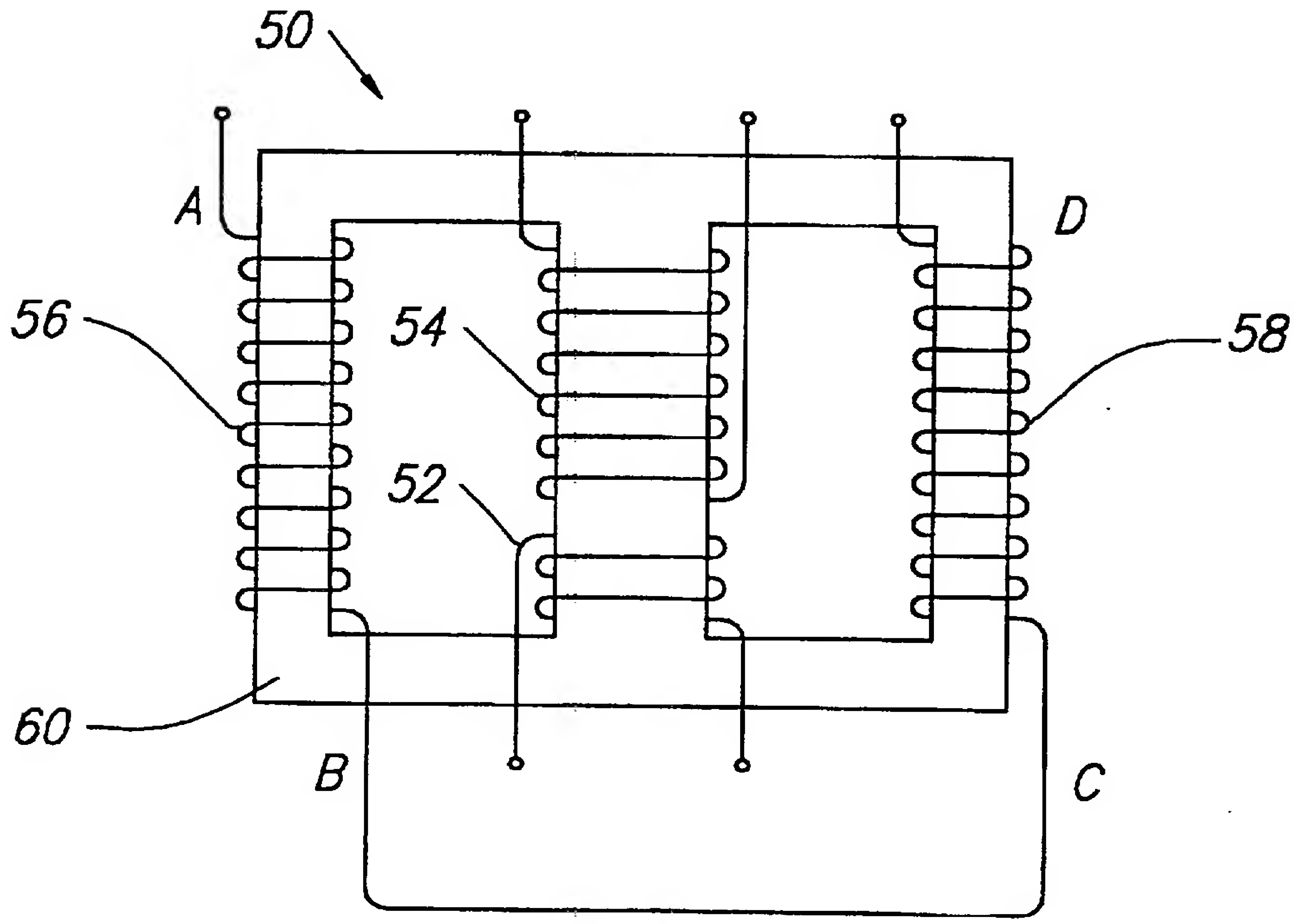

FIG. 4

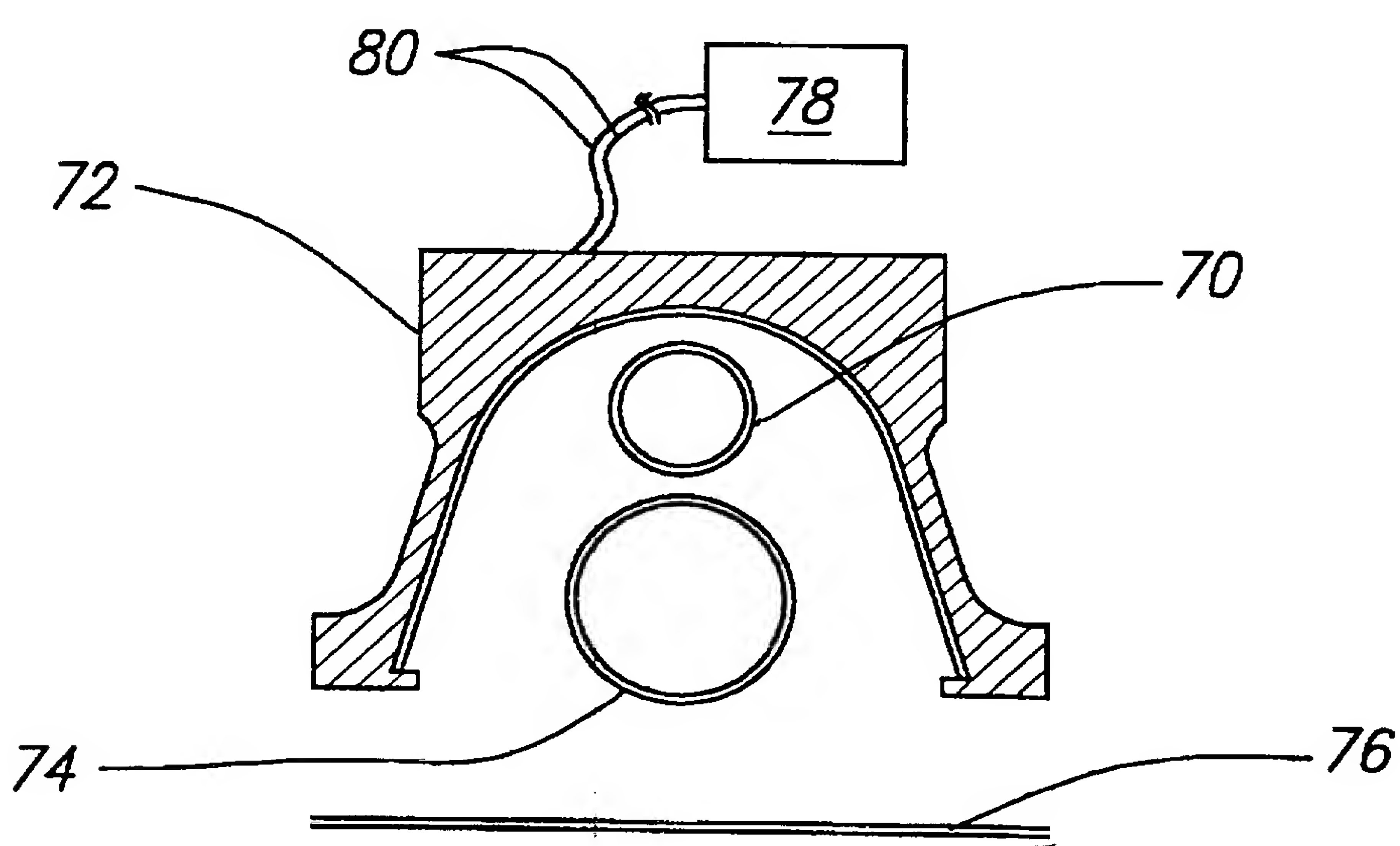

FIG. 5

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POWER SUPPLY INCLUDING A LAMP IGNITOR CIRCUIT

The present invention relates to power supplies for use with discharge lamps, and more particularly to ignitor circuitry for the initial ignition of a lamp.

Discharge lamps require a high voltage at start-up to strike an arc. Ignitor circuits are used to generate high voltage pulses. Depending on the lamp type used the cold striking voltage required is normally 1 to 3 times the lamp running voltage. Known circuits produce a low frequency (typically 50Hz) train of narrow, high amplitude voltage pulses having their main frequency components above 50 kHz.

For an ignitor circuit to be compact, efficient and cost effective, it is preferable for it to operate at high frequency. Often, however, lamps are used in locations a considerable distance from the associated power supply. In particular, lamps are used in the printing and coating industries as a source of ultra-violet radiation for the fast curing of inks and the like on a wide variety of substrate materials. In a large printing press, a lamp and its power supply may be separated by as much as 30 metres. At such a distance, the capacitance of the leads feeding power to the lamp will be about 1nF or more, depending on the thickness of the cable insulation and the separation between the cables. At 50 kHz, 1nF of capacitance has an impedance of some 3kΩ, which will significantly reduce the ignitor voltage output. Known pulse ignitors typically have an internal impedance much greater than this, so in practice, lamp lead capacitance can swamp the ignitor output rendering it substantially ineffective.

To minimize lamp lead capacitance, one could position the ignitor circuit as close as possible to the lamp. However, this is disadvantageous in that it fragments the power supply system and may place the ignitor circuit in a vulnerable position.

Another problem associated with ignition of discharge lamps is that of restarting a lamp quickly after it has extinguished. Once a lamp has been started, it takes about 1 to 2 minutes to "burn in" and reach operating temperature. A mercury vapour lamp, for example, typically operates at about 500°C with a mercury vapour pressure of about two atmospheres. When the lamp is extinguished, a very high voltage is required to re-strike an arc and with existing technology, it is necessary to wait for the lamp to cool before restarting. The consequent downtime of a system reduces productivity.

The present invention provides an ignitor circuit for a discharge lamp, comprising an inductive means connected in parallel with a capacitive means comprising leads for connection to the lamp, the inductive and capacitive means forming a resonant circuit, such that driving the resonant circuit at its resonant frequency generates a high voltage across the leads. Accordingly, the lamp lead capacitance is allowed for by incorporating it into a parallel resonant circuit and therefore it does not compromise the operation of the ignitor.

In a preferred embodiment, the capacitive means includes a variable capacitor. As the lamp lead capacitance is dependent on the particular type of leads used and their length, the variable capacitor enables the resonant frequency of the ignitor circuit to be adjusted as necessary according to the frequency of the drive current to be applied.

The inductive means preferably comprises a secondary winding of a transformer, the circuit being driven by passing current through its primary winding.

The invention further provides a power supply for a discharge lamp comprising a high frequency resonant inverter and an ignitor circuit, the ignitor circuit being driven by a current generated by the resonant inverter. In such a configuration, an ignitor can be cost effectively integrated with the power supply.

Only a small number of additional components may be required to implement the ignitor circuit. Preferably, the ignitor circuit comprises a transformer connected with its secondary winding across a capacitive means, the circuit being driven by passing the inverter current through the primary winding thereof.

The transformer of the ignitor circuit may be selected such that its core saturates when the lamp ignites, thereby substantially reducing the impedance of its secondary winding and automatically disabling the ignitor circuit. Preferably, an additional winding is provided on the transformer, and its core is continuously saturable by passing a saturation current through the additional winding.

An ignitor circuit in accordance with the invention may be capable of generating a sufficient voltage to hot re-strike lamps 46 cm or more in length. Also, even if a lamp is too long for hot re-strike to be possible, the ignitor circuit may still enable the time until re-strike is possible to be dramatically reduced.

According to a further aspect, an apparatus for irradiating a substrate is provided, comprising means for moving a substrate and a discharge lamp relative to each other, and a power supply of the present invention for feeding power to the lamp.

Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings wherein:

Figures 1 and 2 show a portion of a power supply circuit diagram comprising an ignitor of the invention, the power supply being arranged to drive an a.c. lamp, and a d.c. lamp, respectively;

Figure 3 shows a circuit similar to that of Figure 1, but including a different transformer configuration;

Figure 4 shows the transformer of Figure 3; and

Figure 5 shows an apparatus for irradiating a moving substrate.

Figure 1 illustrates the primary features of a power supply in which an ignitor circuit has been incorporated. This power supply configuration and its operation is described in greater detail in the applicant's co-pending British Patent Application no. [ ]. Three sections of the power supply are shown in Figure 1: a resonant inverter 2, a rectifier and d.c. link 4 and a low frequency inverter 6. The power supply of Figure 1 is connected to an a.c. discharge lamp 8.

The resonant inverter 2 comprises two insulated gate bipolar transistors (IGBTs) 10 and 12, two capacitors 14 and 16 and a resonant circuit comprising an inductor 18 and a further capacitor, 20. The input of the rectifier and d.c. link 4 is connected across the capacitor 20. The rectifier consists of four diodes 21 connected so as to form a full-wave bridge. The d.c. link is connected across the rectifier output and includes an inductor 38 and a smoothing capacitor 36.

The d.c. link output across the capacitor 36 is in turn connected to the low frequency inverter 6. The inverter comprises four IGBTs 22, each having a respective pair 24, of protection diodes connected between the collector and emitter thereof.

The ignitor circuit includes a transformer 26 and capacitor 28. The transformer has a primary winding 32 connected in the resonant circuit of the resonant inverter 2 and a secondary winding 34. The secondary winding is connected in parallel with the capacitor 28, and in series with the lamp 8 across the output of the inverter 6. As the secondary winding is in series with the lamp, it must be capable of continuously carrying full lamp current. The capacitance presented by the lamp leads for feeding power to the lamp is represented in the Figure by a capacitor 30.

The capacitor 28 and lamp lead capacitance 30 can be considered to be connected in parallel due to the low impedance return path provided by the protection diodes 24 and the smoothing capacitor 36 of the d.c. link. Accordingly, the total capacitance (C_T) connected across secondary winding 34 is equal to the sum of capacitances 28 and 30. The resonant frequency of the ignitor circuit is therefore defined by the inductance of the secondary winding 34 and C_T. The value of the capacitor 28 is preferably adjusted so that this resonant frequency is slightly higher than that of the resonant inverter 2.

In operation of the circuit of Figure 1, IGBTs 10 and 12 are driven by a control circuit (not shown) which switches them on alternately. The control circuit is connected across the base and emitter of each device via respective inputs 11 and 13. This causes a current to flow in alternating directions through inductor 18, primary winding 32 and capacitor 20. Similarly, IGBTs 22 of the low frequency inverter are switched via inputs 23 under the control of a drive waveform generator (not shown).

The resonant inverter 2 is started at a frequency well above resonance. This frequency is then reduced towards resonance. Reactive power in the resonant inverter therefore increases, thus generating a large resonant voltage and current in the resonant inverter. The voltage is delivered to the lamp via the rectifier, d.c. link 4 and low frequency inverter 6. Resonant current from the resonant inverter is passed through primary winding 32. This drives the ignitor resonant circuit formed by capacitances 28 and 30 and the secondary winding 34. The ratio of inductance to capacitance in this circuit is high so a large voltage is developed across capacitor 28. Tuning of the ignitor resonant frequency as discussed above enables the maximum ignitor voltage to be generated simultaneously with maximum main lamp voltage generation.

Once the lamp strikes, the main low frequency lamp current (typically 10-20A) flows through secondary winding 34. The

transformer 26 is designed so that under these conditions, its ferrite core is saturated. This drastically reduces the impedance of secondary winding 34. This lowered impedance is reflected in the primary winding 32 so the voltage drop thereacross is much reduced. This means the reactive power input to the ignitor is similarly much reduced and the ignitor is therefore automatically disabled.

The circuit illustrated in Figure 2 corresponds to that of Figure 1, except that the low frequency inverter is omitted to enable the circuit to drive a d.c. lamp 38, comprising anode 40 and cathode 42. The operation of the ignitor circuit in the embodiment illustrated in Figure 2 is identical to that of Figure 1, as described above.

Figure 3 shows an alternative circuit to that of Figure 1, which employs a different ignitor transformer configuration. Once the lamp has been struck in the circuit of Figure 1 as described above, the low frequency lamp current flows through the secondary winding 34 of transformer 26 and saturates the transformer core. This current has a square waveform and therefore the magnetic flux in the core passes through zero twice every half-cycle. Under certain operating conditions, the applicants have realised that undesirable instability occurs at the zero crossing points. (This problem does not occur in the circuit of Figure 2, as the lamp is driven with d.c.. The current through the transformer secondary coil 34 is thus undirectional and the transformer core remains continuously saturated).

This problem can be addressed by providing an additional winding on the transformer, and, when appropriate, passing a current through this winding to saturate continuously the transformer. In the circuit of Figure 1, a single additional winding cannot be used as it would develop a large voltage during lamp striking, which would destroy semiconductors utilised in the low frequency inverter 6.

A suitable transformer configuration is shown diagrammatically in Figure 3, as incorporated in the power supply circuit of Figure 1, and a preferred physical arrangement of the transformer is shown in Figure 4. The transformer comprises primary and secondary windings 52 and 54 and two saturation coils 56 and 58 wound around its core 60. The core consists of three limbs, with windings 52 and 54 on the central one and the saturation coils on respective outer limbs. The ends of the coils 56 and 58 are marked A to D to indicate their orientation on the core 60, with respect to their connections in the circuit of Figure 3.

The saturation coils 56 and 58 are arranged on the core 60 such that during striking the high resonant voltage developed across each coil is out of phase with the other and they cancel each other out. Once the lamp has been struck, the magnetic fluxes from each coil add together and saturate the core fully and continuously.

It can be seen that, in the power supply configurations of Figures 1 to 3, the ignitor circuit is current driven by the resonant inverter 2 and therefore only two additional ignitor components are required, namely the transformer 26 and a suitable capacitor 28. The ignitor circuit generates a continuous sinusoidal output across the lamp with a relatively low output impedance, thereby enabling effective lamp starting.

Whilst the illustrated ignitor circuits are driven by the resonant inverter of the power supply, it will be appreciated that an ignitor circuit as described herein may be employed in a "stand-alone" unit built for use in combination with other power supply configurations, including conventional transformer power supplies.

Figure 5 shows an apparatus for irradiating a moving substrate, according to the present invention. An elongate ultra-violet lamp 70 is arranged within an elongate reflective

housing 72. A quartz tube 74 is also provided within the housing 72. Distilled de-ionised water is passed through the tube to filter infra-red radiation from the output of the lamp 70. A conveyor 76 is operable to move substrates bearing curable material past the lamp 70. Power is fed to the lamp from a power supply 78 of the invention, via leads 80. As discussed above, in practice the power supply 78 is often located a considerable distance from the lamp 70.

CLAIMS

1 An ignitor circuit for a discharge lamp, comprising an inductive means connected in parallel with a capacitive means comprising leads for connection to the lamp, the inductive and capacitive means forming a resonant circuit, such that driving the resonant circuit at its resonant frequency generates a striking voltage across the leads.

2 A circuit of Claim 1 wherein the capacitive means includes a variable capacitor.

3 A circuit of Claim 1 or Claim 2 wherein the inductive means comprises a secondary winding of a transformer, the circuit being driven by passing current through its primary winding.

4 A power supply for a discharge lamp comprising an ignitor circuit of any preceding claim.

5 A power supply for a discharge lamp comprising a high frequency resonant inverter and an ignitor circuit, the ignitor circuit being driven by a current generated by the resonant inverter.

6 A power supply of Claim 5 wherein the ignitor circuit comprises a transformer connected with its secondary winding across a capacitive means, the circuit being driven by passing the inverter current through the primary winding thereof.

7 A power supply of Claim 6 wherein the secondary winding of the transformer and a capacitive means of the ignitor circuit form a resonant circuit having a resonant frequency greater than that of the resonant inverter.

8 A circuit of Claim 3 or a power supply of Claim 6 or Claim 7 wherein the transformer core is adapted to saturate when the

lamp ignites thereby disabling the ignitor circuit.

9 A circuit or power supply of Claim 8 wherein an additional winding is provided on the transformer, and its core is continuously saturable by passing a saturation current through the additional winding.

10 A circuit or power supply of Claim 9 wherein the additional winding comprises two coils arranged such that voltages developed across each coil substantially cancel out.

11 A power supply of Claim 9 or Claim 10 wherein the resonant inverter is connected to a d.c. link and the saturation current is fed from the d.c. link.

12 A circuit of any of Claims 1 to 3 and 8 to 10 or a power supply of any of Claims 4 to 11 wherein the ignitor circuit is operable to generate a sinusoidal output across said lamp.

13 Apparatus for irradiating a substrate, comprising means for moving a substrate and a discharge lamp relative to each other, and a power supply of any of Claims 4 to 12 for feeding power to the lamp.

14 An ignitor circuit substantially as described herein with reference to the accompanying drawings.

15 A power supply substantially as described herein with reference to the accompanying drawings.

16 Apparatus for irradiating a substrate substantially as described herein with reference to the accompanying drawings.

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Application No:	GB 9901249.4	**Examiner:**	M J Billing
Claims searched:	1 to 4	**Date of search:**	9 April 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H2H HLD51, HLD61, HLD631.

Int Cl (Ed.6): H05B 41/14, 41/16, 41/20, 41/23, 41/231, 41/232, 41/233, 41/24, 41/26, 41/28, 41/29.

Other: ONLINE - EDOC, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB1112255	(DONATO) - page 2 lines 3-11	1,3,4 at least
X	GB0774477	(TOUVET) - whole document	1,4 at least
X	EP0647086A1	(FUJIMURA) - Fig.2; column 6 lines 36-55	1,3,4 at least
X	EP0178852A1	(THOMAS) - Fig.3; page 8 lines 18-27	1,3,4 at least
X	WO97/33456A1	(BOSCH) - Fig.1; Abstract	1,3,4 at least
X	WO97/16054A1	(AUCKLAND UNISERVICES) - Fig.2; page 8 lines 12-21	1,4 at least
X	WO91/02443A1	(AMERICAN STERILIZER) - Fig.1; page 13 line 7 to page 14 line 3	1,3,4 at least
X	CA2224300	(MATSUSHITA) - Figs.7a,7b; page 13 line 25 to page 14 line 28	1,4 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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